DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
and Prevention (CDC)
Atlanta GA 30333

May 21, 2001

Todd Damrow, Ph.D., M.P.H.
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Dear Dr. Damrow:

Enclosed you will find the trip report from Epi-Aid #2001-07 conducted in November 2000 in Montana. The objective of the investigation was to determine if increases in respiratory and cardiovascular hospital admissions occurred during last season's forest fires in four counties experiencing varying levels of exposure. The data collected during this investigation have been analyzed and summarized in this trip report. We appreciate having the opportunity to participate in this study and hope you find this report useful. Should you have any questions, or suggestions for future analyses please feel free to contact one of us at (404) 639-2541 or (404) 639-2547.

Sincerely,

R. Charon Gwynn

R. Charon Gwynn, PhD

Joshua A Mott

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Background

During the late summer of 2000, forest fires in Montana burned approximately 950,000 acres. Approximately one third of this burn occurred in the Bitterroot Valley, located in the southwestern part of the state. Smoke plumes from the fires spread to nearby counties, resulting in levels of particulate matter (PM) that exceeded the EPA 24-hour standard of 150 $\mu g/m^3$ on several occasions. The Bitterroot Valley experienced elevated smoke levels during the months of July and August, with the highest levels in Ravalli County (pop. ~ 35,000). During the peak period of the fire, residents of approximately 700 homes were evacuated in Ravalli County, most of who temporarily relocated to Missoula County. Concerns of potential adverse health effects in these communities prompted a request for assistance from the Montana Department of Health to determine the health consequences from forest fire related smoke from forest fires.

Components of smoke from forest fires include particulate matter (PM), carbon monoxide, formaldehyde, acrolein, benzene, nitrogen dioxide, polycyclic aromatic hydrocarbons (PAH's), and volatile organic compounds. PM, in particular, has been the subject of recent concern and regulation. PM is a non-chemically specific compound that has been associated with a variety of adverse health outcomes in many different locations. Several studies have demonstrated consistent associations between ambient PM levels and increases in hospital admissions [1, 2], and mortality [3-5]in various urban areas, both in the US and abroad.

While health effects have been demonstrated in urban areas, the composition of biomass PM differs from that of PM in urban areas. Urban PM is largely comprised of secondary products, such as sulfates and ozone, that result from combustion of fossil

fuels. PM resulting from biomass burning is comprised largely of elemental and organic carbon, as well as PAH's and trace metals [6]. Despite the differences in composition, respiratory related health effects have been associated with biomass burning. For example, PM exposure from wood burning stoves has been associated with increased cough symptoms [7] as well as an increased risk for acute lower respiratory illness [8]. However, less is known about the health risks associated with PM from forest-fires. Health effects such as decreased lung function [9, 10] and increased prevalence of respiratory symptoms [10-12] have been observed in firefighters. However, these associations are limited by the lack of adequate exposure data. Additionally, there is little information of the effects of smoke from forest fires on communities living near forest fires. Thus, there is a need to better understand the health impact of smoke from forest fires on the general population, given the reported health effects associated with occupational exposure to smoke from forest fires.

Objective

Given these demonstrated health effects associated with PM, we proposed the hypothesis that populations that experienced elevated smoke levels due to nearby forest fires will experience increases in severe health outcomes, such as hospital admissions. Therefore, the goal of the investigation was to quantify and compare the change in hospital admission rates from 1999 to 2000 for cardiovascular and respiratory illnesses in four counties experiencing varying levels of smoke from forest fires.

Methods

Study Area

We selected four counties for evaluation in this investigation based on their proximity to the fires occurring in the Bitterroot Valley and the availability of environmental monitoring data. We selected Ravalli County as the highly exposed area, Missoula and Lewis & Clark Counties as the moderate exposed area and Yellowstone County to represent a low exposed area.

Particulate Matter Data

The Montana Department of Environmental Quality (DEQ) routinely measures concentrations of ambient pollutants throughout the state. During the time period of the study, the DEQ measured particulate matter (PM) in each of the four counties. Hourly PM measurements were available for Ravalli, Missoula, and Lewis & Clark counties, while 24-hour PM measurements were available only once every six days in Yellowstone County. Figure 1 depicts the location of PM monitor used to collect the environmental data. The sites in Ravalli, Lewis & Clark, and Missoula counties collect daily PM data , while the site in Yellowstone County collected only PM data once every six days.

Case Definition and Ascertainment

We requested inpatient admission records for all cardiovascular (ICD9 codes: 390-459) and respiratory (ICD9 codes: 460-519 primary discharge diagnoses) for the period of July 1 through September 15, 1999 and 2000 from all inpatient hospital facilities servicing residents of the four counties. We excluded admissions from the study if the admission was: a transfer from another hospital, for a scheduled elective procedure, an admission to a transitional care unit, or if the patient was not a resident of one of the

four selected counties. Information abstracted from the medical record included: primary and secondary discharge diagnosis, history of illness; county of residence, data of admissions and discharge, and demographic information (see chart abstraction form in Appendix A).

Rate Calculation

We calculated monthly and 3-month hospitalization rates for each year by dividing the total number of admissions for residents of each county by the 1999 Census population estimate for that county. We evaluated the following disease classifications : total cardio respiratory, respiratory, chronic obstructive pulmonary disease (COPD), pneumonia, circulatory, ischemic heart disease , dysrhythmia, heart failure , and cerebrovascular disease. We calculated rates for the high, moderate and low exposure areas.

Estimation of Effect

To assess the effect of living in an exposed county in 2000 compared to living in an unexposed county in 2000 we computed rate ratios. We calculated the risk of being admitted to the hospital for total cardio respiratory, respiratory, chronic obstructive pulmonary disease (COPD), pneumonia, circulatory, ischemic heart disease , dysrhythmia, heart failure , and cerebrovascular disease for the moderate and the high exposed areas, using the unexposed county as the reference group

To assess the change in admissions during the period of the fire compared to a baseline period with no fires we computed rate ratios for each exposure where admissions from the 2000 study period was the exposure group and admissions from the 1999 study period was the no exposure period.

Results

Hospital Admission Data

We abstracted a total of 2,275 medical records for patients living in the four counties during both the 1999 and 2000 study periods. The distribution of these admissions according to ICD9 codes are shown in Tables 1 and 2 for the three exposed counties and Yellowstone County for circulatory and respiratory admissions, respectively. The circulatory admissions disease categories with the greatest number of admissions were ischemic heart disease, dysrhythmia, heart failure, and cerebrovascular disease, while those with the greatest number of admissions within the respiratory category were COPD and pneumonia.

Particulate Matter Data

We found that PM levels in Ravalli, Missoula, and Lewis and Clark were higher in 2000 than in 1999, while that of Yellowstone was unchanged (Table3). The mean of daily 24-hour average concentrations and the mean of the peak hour concentration are presented for Ravalli, Missoula, and Lewis & Clark, while the 24-hour average is shown for Yellowstone. In 2000, Ravalli County had the highest mean PM level (47.0 $\mu g/m^3$), Missoula and Lewis & Clark Counties had moderate PM levels (34.2 and 32.6 $\mu g/m^3$, respectively), and Yellowstone County had the lowest PM level (23.7 $\mu g/m^3$). The increases in mean PM level between 1999 and 2000 for each county are illustrated in Figure 2. The PM levels began to increase in late July in Ravalli, Missoula and Lewis & Clark Counties, consistent with the peak fire period (Figure 3). In contrast, Yellowstone County experienced much lower levels that did not change over time.

County & Month-Specific Admission Rates

We found increases in hospital admission rates between 1999 and 2000 for the total respiratory and COPD hospital admissions category for June, July and August in Ravalli County (Table 4). Alternatively, we did not observe consistent increases for pneumonia admissions. In Missoula County, we found increases in each of the respiratory hospital admission rates for each month, as well as for the overall 3-month period. We observed increases in each of the respiratory admissions in Lewis and Clark County for the months of July and August, as well as the total 3-month period. In Yellowstone County, we found decreases in all respiratory admission rates for most months, as well as the total 3-month period.

For the circulatory admissions outcomes, we observed consistent increases in admission rates in Ravalli County for total circulatory, ischemic heart disease, heart failure, and cerebrovascular disease for each month of the study, as well as the overall 3-month study period (Table 5). Atlernatively, Missoula, Lewis & Clark, and Yellowstone counties demonstrated less consistent changes in admission rates across the study period months.

Admission Rates by Exposure Level

We calculated three-month admission rates for high, moderate and low exposure levels, where Ravalli County represented the high exposure area, Missoula and Lewis & Clark Counties represented the moderate exposure area, and Yellowstone County represented the low exposure area. The high exposure area demonstrated consistent increases in the 3-month respiratory and circulatory hospital admissions rates (Table 6). The only outcome that did not demonstrate an increase in the high exposure group was

dysrhythmia, however the number of admissions in this category was only 10 in 1999 and 4 in 2000 (see Appendix B). In the moderate exposure category, we found somewhat smaller increases in the respiratory admissions categories while changes in the circulatory categories were less consistent (Table 6). Consistent decreases in respiratory admissions occurred in the low exposure area (Table 6). Alternatively, we found increases in several of the circulatory outcomes in the low exposure area. With the exception of the dysrhythmia admissions, the magnitude of all the increases in the low exposed area was less than that of the high exposed area.

To assess if the change in admission rate increased with increased exposure, we plotted the changes in admission rates by exposure for each of the hospital admissions categories (Figures 4 & 5), using county of residence as a proxy for exposure. Those discharge diagnoses categories demonstrating a clear exposure-response relationship are shown in Figure 4, while those where this relationship is not evident are shown in Figure 5. We found that all outcomes, except dysrhythmia, had larger increases in admission rate in the highly exposed area than that of the low exposed area.

Estimation of Effect

The rate ratios for disease-specific hospital admissions during 2000 for the moderate and high exposed areas compared to the unexposed area are shown in Table 7. In the highly exposed area, statistically significant rate ratios greater than one were observed for the combined cardio-respiratory, respiratory, COPD, circulatory, and ischemic heart disease categories. Alternatively, we observed no positive significant relationships for the moderate exposure category. In fact, the rate ratios for heart failure

and cerebrovascular disease in the moderate exposure category indicated a lower risk for admission than that of the low exposure area.

When comparing the rate of admission in 2000 with that of 1999 for each exposure level, the high exposure county had positive significant rate ratios for the combine cardio-respiratory, total respiratory, COPD, circulatory, and IHD (Table 8). In the moderate exposure counties, the rate ratios for the combine cardio-respiratory, total respiratory, pneumonia, and dysrhythmia were statistically significant. In the high exposure county, only cerebrovascular disease demonstrated and increased risk. These rate ratios are illustrated in Figure 6. In general, the outcomes that demonstrated significant increased risk in the high exposure area had rate ratios that increased in magnitude from the low exposure county to the high exposure county.

Exposure-Response Relationship

To assess the temporal nature of the PM-hospital admission relationship, we plotted weekly mean PM levels and the weekly sums of respiratory related hospital admissions for 1999 and 2000, in the combined moderate and high exposed counties. We found that the respiratory related hospital admissions were higher and more variable in 2000 than they were in 1999 (Figures 7a and 7b). However, no exposure-response relationship is evident. Additionally, increases in hospital admissions were observed prior to the increase in PM_{10}. Similarly, the temporal relationship between PM elevations and circulatory hospital admissions is not evident (Figures 8a and 8b).

Discussion

The purpose of this investigation was to determine if exposure to smoke from forest fires from fires was associated with a severe health outcome indicator, admission to

a hospital for a respiratory or cardiovascular illness. We found that the risk of respiratory and circulatory admission in the high exposure county during the 2000 study period was significantly greater than that of the low exposure county. Additionally, in the counties with smoke exposure in 2000 the risk of respiratory and circulatory admission was significantly greater during the 2000 study period than that of 1999. Outcomes that exhibited clear dose-response relationships when plotted by exposure county included the combined cardio-respiratory category, total respiratory, total circulatory, COPD and IHD. These results suggest that for certain health outcomes higher exposures to smoke from forest fires may result in increases in hospital admissions.

While an exposure-response relationship is evident for several outcomes when changes in admission rates were plotted by exposure level, not all outcomes followed this pattern. For example, the change in admission rate for cerebrovascular disease and heart failure was lower in the moderate exposure area than the low exposure counties. Additionally, the change in admission rate for pneumonia and dysrhythmia was lower in the high exposure area than that of the moderate exposure area. One possible reason for the lack an exposure-response relationship for certain outcomes is that misclassification of exposure occurred in the moderate category. The two counties that represent the moderate exposure areas are large areas that likely experienced varying levels of exposure. Therefore, it is possible that some of the admissions from areas with very high levels of exposure were wrongly classified into the moderate group, resulting in an underestimation of effect in the high exposure category and a overestimation of effect in the moderate category. Investigations into the spatial variation of PM levels within each of the exposure areas having multiple PM monitors would be needed to evaluate the

possibility of exposure misclassification. This potential exposure misclassification underscores the need for a biomarker of smoke from forest fires that can be readily used in the field as an indication of personal exposure.

Another limitation of this analysis is the possibility that there may have been out migration of susceptible populations during the peak period. This would result in an underestimation of the effect of the fire smoke in the high exposed county. While the movement of populations during the fire cannot be completely ascertained, the organized evacuations generally displaced people from Ravalli County to Missoula County. Therefore, people who participated in these organized evacuations have been captured in the study.

During the study period a temporal exposure-response relationship between PM and hospital admissions was not evident. The increases in respiratory and circulatory hospital admissions prior to the increase in PM_{10} seen in Figures 7b & 8b, could be due to small increases in PM level not seen in this data which is aggregated both on a weekly level as well as for the three exposed counties. During early July, several increases in the peak hourly PM measurement occurred in Ravalli and Lewis & Clark counties (Appendix C). During this period, fires were burning in the bordering town of Salmon, ID that may have resulted in hospital admissions in Ravalli. More detailed investigations into the temporal exposure-response relationship are necessary. Future analyses will be conducted on a county level, utilizing Poisson time-series regression methods to determine the effect of day-to-day increases in PM on hospital admissions. The Poisson distribution, which is used for count data, will allow for the quantification of effects on a county level where the daily number of admissions are small. The advantage of

conducting analyses on a county level will be the ability to use geographically specific PM exposure data, limiting the potential for misclassification. These analyses will provide for a better understanding of the temporal exposure response association.

In summary, we found increases in respiratory and circulatory admissions, more specifically COPD and ischemic heart disease, in counties exposed to elevated levels of fire smoke. These increases occurred during the months when the peak fire period and PM levels were elevated. An exposure-response gradient was observed by exposure area, where the more highly exposed areas experienced the largest increases in respiratory hospital admissions. Further analyses are necessary to assess the temporal nature of this relationship. Given the severity of the hospital admission outcome, and the widespread nature of exposure to smoke from forest fires, forest fires represent a serious public health threat. A better understanding of the impact of forest fire smoke on those with pre-existing illness as well as the development of smoke biomarkers are needed in order to develop appropriate research-based intervention recommendations for future fires.

References

1. Schwartz, J., *Air pollution and hospital admissions for the elderly in Birmingham, Alabama.* American Journal of Epidemiology, 1994. **139**(6): p. 589-98.
2. Schwartz, J. and R. Morris, *Air pollution and hospital admissions for cardiovascular disease in Detroit, Michigan.* American Journal of Epidemiology, 1995. **142**(1): p. 23-35.
3. Schwartz, J., *What are people dying of on high air pollution days?* Environmental Research, 1994. **64**(1): p. 26-35.
4. Dockery, D.W., J. Schwartz, and J.D. Spengler, *Air pollution and daily mortality: associations with particulates and acid aerosols.* Environmental Research, 1992. **59**(2): p. 362-73.
5. Pope, C.A., J. Schwartz, and M.R. Ransom, *Daily mortality and PM10 pollution in Utah Valley.* Archives of Environmental Health, 1992. **47**(3): p. 211-7.
6. Goh, K., D. Schwela, J. Goldammer, and O. Simpson, eds. *Health Guidelines for Vegetation Fire Events*. 1999.
7. Ellegard, A., *Cooking fuel smoke and respiratory symptoms among women in low-income areas in Maputo.* Environmental Health Perspectives, 1996. **104**(9): p. 980-5.
8. Robin, L.F., P.S. Less, M. Winget, M. Steinhoff, L.H. Moulton, M. Santosham, and A. Correa, *Wood-burning stoves and lower respiratory illnesses in Navajo children.* Pediatric Infectious Disease Journal, 1996. **15**(10): p. 859-65.
9. Stone, R., *Wood smoke fires infections.* Science, 1995. **267**: p. 1771.

10. Rothman, N., D.P. Ford, M.E. Baser, J.A. Hansen, T. O'Toole, M.S. Tockman, and P.T. Strickland, *Pulmonary function and respiratory symptoms in wildland firefighters.* Journal of Occupational Medicine, 1991. **33**(11): p. 1163-7.

11. Sutton, P. and J. Castorina, *Carbon monoxide exposure in firefighters*. 1988, CA Department of Health: Berkeley. CA.

12. Liu, D., I.B. Tager, J.R. Balmes, and R.J. Harrison, *The effect of smoke inhalation on lung function and airway responsiveness in wildland fire fighters.* American Review of Respiratory Disease, 1992. **146**(6): p. 1469-73.

Table 1. Counts of circulatory admissions by ICD9 codes in exposed and unexposed areas, 1999 & 2000

	ICD9 Code	Ravalli, Missoula and Lewis & Clark Counties		Yellowstone County	
		1999	2000	1999	2000
	390	0	1	0	0
	391	0	1	0	0
	394	0	1	1	0
	396	0	1	1	0
	398	2	7	7	2
	401	1	2	1	2
	402	0	3	2	2
	403	2	0	2	0
	404	0	0	0	1
	405	1	0	1	0
Ischemic Heart Disease	**410**	**45**	**66**	**35**	**37**
Ischemic Heart Disease	**411**	**4**	**12**	**1**	**3**
Ischemic Heart Disease	**413**	**7**	**1**	**0**	**1**
Ischemic Heart Disease	**414**	**88**	**103**	**54**	**51**
	415	10	13	8	13
	416	3	2	0	1
	417	1	0	0	0
	420	0	2	3	1
	421	1	2	1	0
	422	0	1	0	0
	423	1	2	1	2
	424	1	2	0	0
	425	0	2	0	2
	426	5	6	4	3
Dysrhythmia	**427**	**44**	**61**	**39**	**35**
Heart Failure	**428**	**56**	**62**	**48**	**69**
	429	0	3	0	2
Cerebrovascular Disease	**430**	**3**	**0**	**1**	**2**
Cerebrovascular Disease	**431**	**3**	**2**	**6**	**7**
Cerebrovascular Disease	**432**	**3**	**1**	**1**	**1**
Cerebrovascular Disease	**433**	**12**	**9**	**5**	**14**
Cerebrovascular Disease	**434**	**25**	**33**	**22**	**39**
Cerebrovascular Disease	**435**	**12**	**13**	**17**	**18**
Cerebrovascular Disease	**436**	**14**	**11**	**3**	**6**
Cerebrovascular Disease	**437**	**2**	**4**	**2**	**2**
	438	**3**	**1**	**0**	**1**
	440	8	4	6	2
	441	5	0	0	3
	442	0	0	0	2
	443	0	0	0	1
	444	2	2	1	1
	446	0	3	4	1
	447	1	0	0	0
	448	0	0	1	0
	451	0	0	0	4
	452	0	0	1	0
	453	8	10	5	10
	454	0	1	0	0
	455	1	1	0	2
	456	0	1	2	0
	457	0	0	1	0
	458	5	7	3	4
	459	0	2	0	1

Table 2. Counts of respiratory admissions by ICD9 codes in exposed and unexposed areas, 1999 & 2000

	ICD9 Code	Ravalli, Missoula and Lewis & Clark Counties		Yellowstone County	
		1999	2000	1999	2000
	461	0	1	1	0
	463	0	2	2	0
	464	1	2	1	1
	465	0	0	2	0
	466	4	4	8	5
	473	2	0	0	0
	475	1	3	0	2
	478	1	3	1	0
	480	3	1	3	0
	481	4	6	2	5
	482	8	9	12	9
	483	0	0	1	0
	485	2	1	0	0
Pneumonia →	**486**	**40**	**70**	**50**	**38**
	487	0	0	1	0
	490	1	1	0	1
	491	35	48	40	33
COPD	492	0	1	1	1
	493	12	16	16	11
	494	1	0	2	0
	495	0	1	0	0
	496	5	9	1	3
	507	8	10	11	15
	508	1	0	3	0
	510	0	0	2	3
	511	3	6	1	2
	512	4	5	3	5
	515	1	1	2	0
	516	2	5	4	0
	518	11	7	16	16
	519	0	1	0	0

Table 3. 1999 & 2000 Particulate Matter Data in 4 Montana Counties, July 1- September 15.

Year	County	24-hr Average Concentration		Peak Hour Concentration	
		Mean	SD	Mean	SD
1999	Ravalli	15.5	5.3	33.5	14.5
	Missoula	17.7	5.5	43.9	26.8
	Lewis & Clark	18.8	8.0	58.3	29.7
	Yellowstone	23.5	12.6	NA	NA
2000	Ravalli	47.0	61.2	150.7	189.5
	Missoula	34.2	36.8	85.4	92.8
	Lewis & Clark	32.6	22.7	93.0	106.2
	Yellowstone	23.7	10.3	NA	NA

Table 4. 1999 & 2000 Rate of Admission (per 10,000 population) for Respiratory Causes by Month.

County	Month	Total		COPD		Pneumonia	
		1999	2000	1999	2000	1999	2000
Ravalli	July	5.0	8.7	1.4	3.1	3.1	1.4
	August	2.2	5.6	1.1	2.8	0.3	1.4
	September	1.4	2.2	0.8	1.4	0.0	0.6
	Total	8.7	16.4	3.4	7.3	3.4	3.4
Missoula	July	2.7	2.9	0.8	0.6	1.1	1.7
	August	2.7	4.1	0.9	1.3	1.0	2.0
	September	1.0	1.7	0.6	0.7	0.3	0.8
	Total	6.4	8.7	2.2	2.7	2.5	4.5
Lewis & Clark	July	4.1	5.7	1.1	1.5	1.7	3.1
	August	4.4	5.7	2.0	2.4	1.3	2.2
	September	2.9	2.8	0.9	0.9	1.3	1.1
	Total	11.5	14.2	4.1	4.8	4.3	6.5
Yellowstone	July	5.7	5.2	1.8	1.6	1.9	1.7
	August	6.0	4.6	1.7	1.7	2.3	1.7
	September	3.0	1.8	1.3	0.6	1.3	0.7
	Total	14.7	11.7	4.7	3.9	5.4	4.1

Table 5. 1999 & 2000 Rate of Admission (per 10,000 population) for Circulatory Causes by Month.

County	Month	Total		IHD		Dysrhythmia		Heart Failure		CVD	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Ravalli	July	8.1	16.8	3.4	8.1	1.4	0.8	1.7	2.5	1.4	2.5
	August	10.1	12.8	4.7	5.6	0.6	0.2	2.0	2.5	1.4	2.5
	September	3.9	5.0	1.1	2.0	0.8	0.0	0.0	0.8	1.1	1.7
	Total	22.1	34.6	9.2	15.6	2.8	1.1	3.6	5.9	3.9	6.7
Missoula	July	8.2	8.4	2.1	2.9	1.1	1.0	1.6	1.0	1.7	1.6
	August	8.6	7.7	4.0	3.1	1.0	1.3	0.7	0.9	1.6	1.1
	September	2.5	4.0	1.2	2.0	1.0	1.1	0.6	0.2	0.6	0.6
	Total	19.3	20.1	7.4	8.1	3.1	3.5	2.8	2.1	3.8	3.2
Lewis & Clark	July	8.0	9.8	1.7	4.1	0.9	1.3	1.3	1.5	2.6	0.9
	August	9.6	11.7	4.6	3.3	0.7	2.8	0.7	1.1	2.0	1.8
	September	6.3	7.8	2.0	2.6	1.1	0.7	1.3	1.5	0.9	1.1
	Total	23.9	29.2	8.3	10.0	2.8	4.8	3.3	4.4	5.5	3.9
Yellowstone	July	8.6	12.2	2.4	3.1	1.3	1.1	1.1	2.4	2.0	2.5
	August	9.7	10.9	3.1	3.0	1.3	1.3	1.9	1.9	2.0	3.4
	September	4.6	4.4	1.7	1.1	0.4	0.4	0.8	1.1	0.5	1.1
	Total	23.0	27.5	7.1	7.2	3.1	2.8	3.8	5.4	4.5	7.1

Table 6. 1999 & 2000 Rate of Admission (per 10,000 population) for Circulatory Causes by Month.

Exposure Category	Discharge Diagnosis	Admission Rate		Percent Increase
		1999	2000	
High (Ravalli)	Respiratory	8.6	16.4	90.3
	COPD	3.4	7.3	116.7
	Pneumonia	3.4	3.4	0.0
	Circulatory	22.1	34.6	57.0
	IHD	9.2	15.6	69.7
	Heart Failure	3.6	5.9	61.5
	Dysrhythmia	2.8	1.1	-60.0
	CVD	3.9	6.7	71.4
Moderate (Missoula and Lewis & Clark)	Respiratory	8.3	10.8	30.3
	COPD	2.9	3.5	19.0
	Pneumonia	3.1	5.2	66.7
	Circulatory	21.0	23.6	12.3
	IHD	7.7	8.9	13.5
	Heart Failure	3.0	2.9	-4.7
	Dysrhythmia	2.4	4.0	67.6
	CVD	4.7	3.7	-21.9
Low (Yellowstone County)	Respiratory	14.7	11.7	-20.3
	COPD	4.7	3.9	-18.3
	Pneumonia	5.4	4.1	-24.6
	Circulatory	23.0	27.5	19.5
	IHD	7.1	7.2	2.2
	Heart Failure	3.8	5.4	43.8
	Dysrhythmia	3.1	2.8	-10.3
	CVD	4.5	7.1	57.9

Table 7.Rate Ratios for Admission in Exposed Areas Compared to Unexposed Area in 2000

Disease	Moderate Exposure Rate Ratio (95% CI)	High Exposure Rate Ratio (95% CI)
Cardio-respiratory	0.87 (0.77-0.99)	1.30 (1.10-1.54)
Respiratory	0.96 (0.86-1.07)	1.29 (1.04-1.60)
COPD	0.95 (0.78-1.16)	1.58 (1.16-2.15)
Pneumonia	1.11 (0.96-1.29)	0.85 (0.51-1.42)
Circulatory	0.93 (0.86-1.00)	1.19 (1.02-1.39)
IHD	1.09 (0.97-1.22)	1.72 (1.40-2.12)
Heart Failure	0.70 (0.55-0.90)	1.06 (0.73-1.54)
Dysrhythmia	1.17 (1.00-1.37)	0.47 (0.18-1.18)
CVD	0.67 (0.54-0.84)	0.96 (0.67-1.37)

Table 8.Rate Ratios for Admission in 2000 Compared to 1999 for Each Exposure Level

	Unexposed rate ratio (95%CI)		Moderate Exposure rate ratio (95%CI)		High Exposure rate ratio (95%CI)	
Cardio-respiratory	1.04	(0.92-1.18)	1.17	(1.03-1.34)	1.67	(1.31-2.11)
Respiratory	0.79	(0.64-0.99)	1.30	(1.03-1.65)	1.90	(1.23-2.94)
COPD	0.82	(0.56-1.19)	1.19	(0.79-1.79)	2.17	(1.09-4.3)
Pneumonia	0.75	(0.53-1.08)	1.67	(1.15-2.41)	1.00	(0.45-2.23)
Circulatory	1.20	(1.02-1.39)	1.12	(0.96-1.31)	1.57	(1.18-2.08)
IHD	1.02	(0.76-1.37)	1.14	(0.88-1.47)	1.70	(1.10-2.61)
Heart Failure	1.44	(0.99-2.08)	0.95	(0.62-1.46)	1.62	(0.81-3.23)
Dysrhythmia	0.90	(0.57-1.42)	1.68	(1.10-2.56)	0.40	(0.13-1.28)
CVD	1.58	(1.13-2.20)	0.78	(0.54-1.13)	1.71	(0.89-3.31)

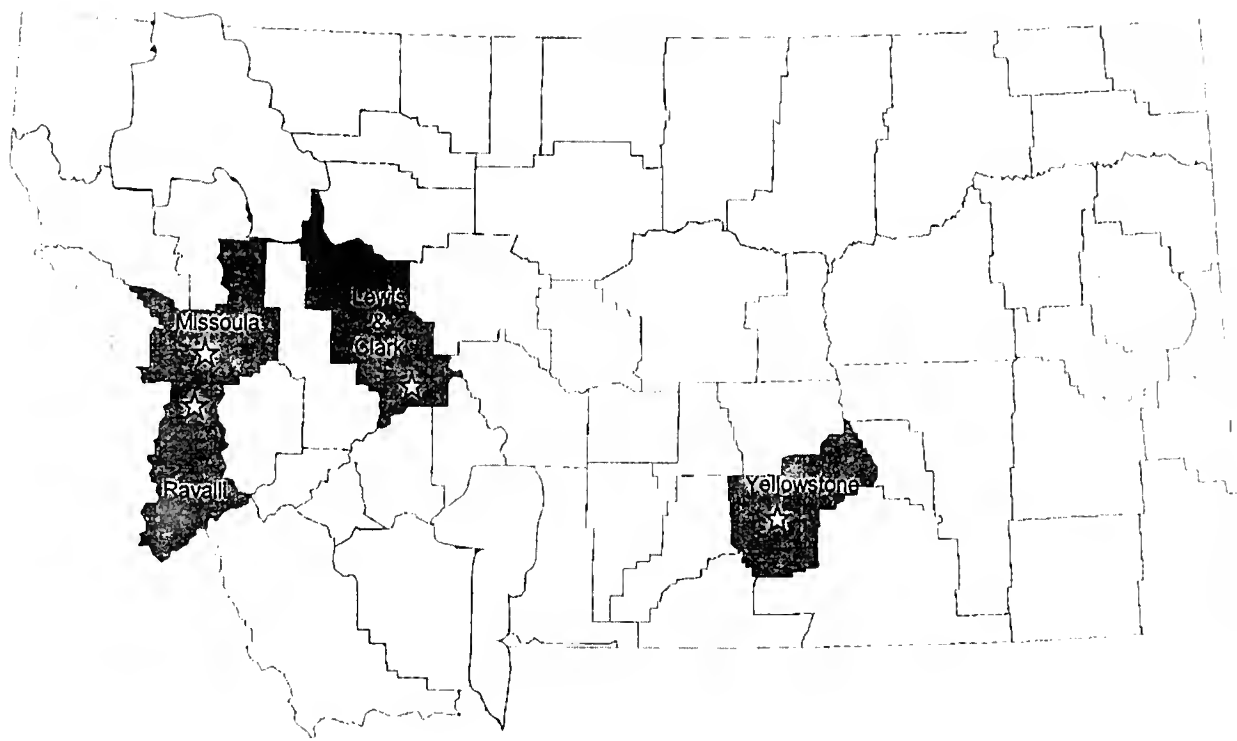


Figure 1. Location of PM10 Monitors used in analysis.

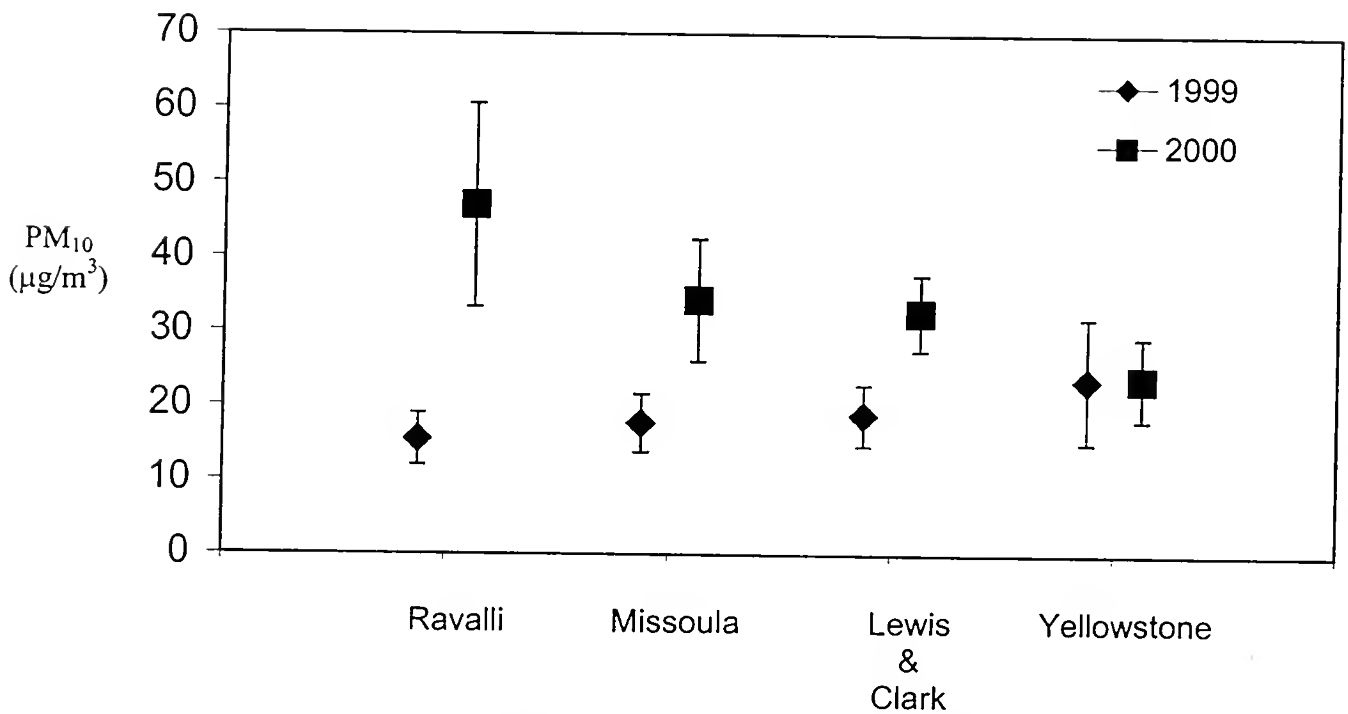


Figure 2. Average PM_{10} concentration during Study Period in Each County, 1999 & 2000

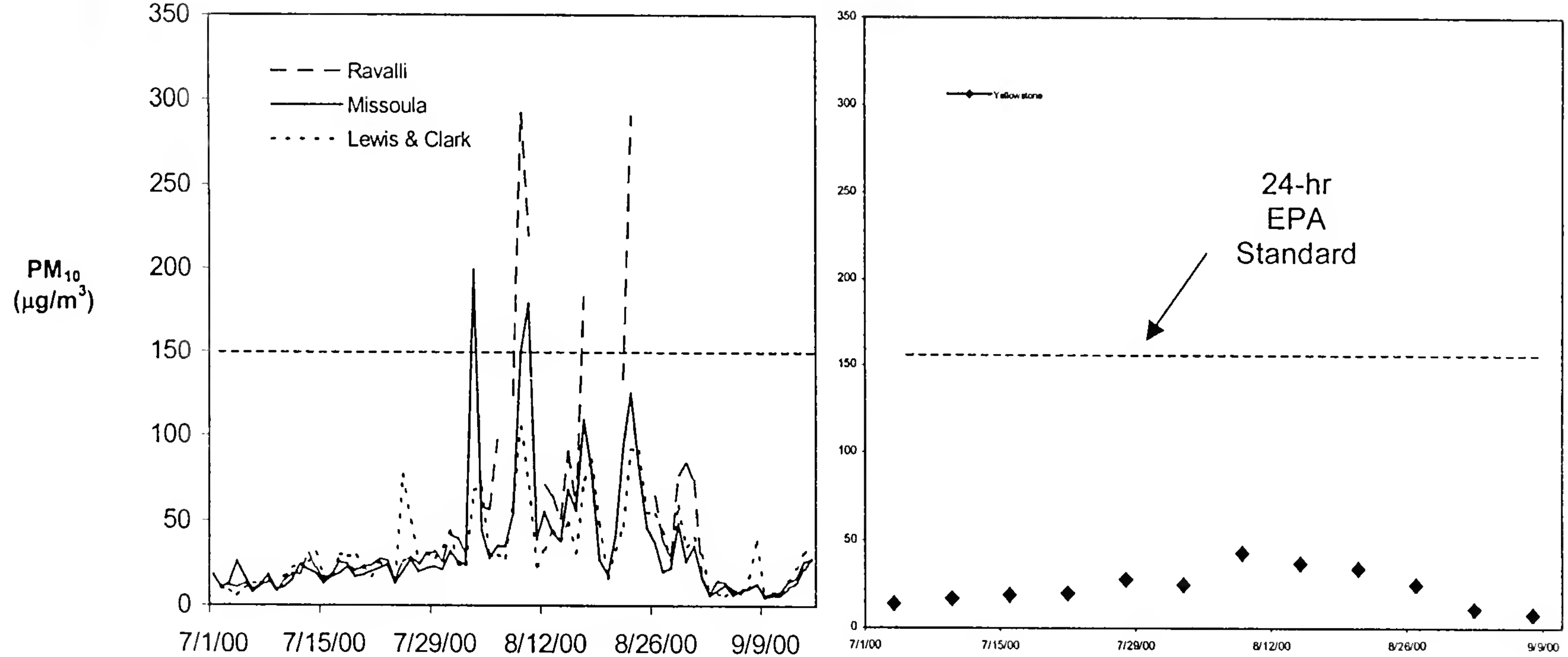


Figure 3. Time-Series Plots of Daily 24-hour Average PM_{10} Values in 4 Montana Counties

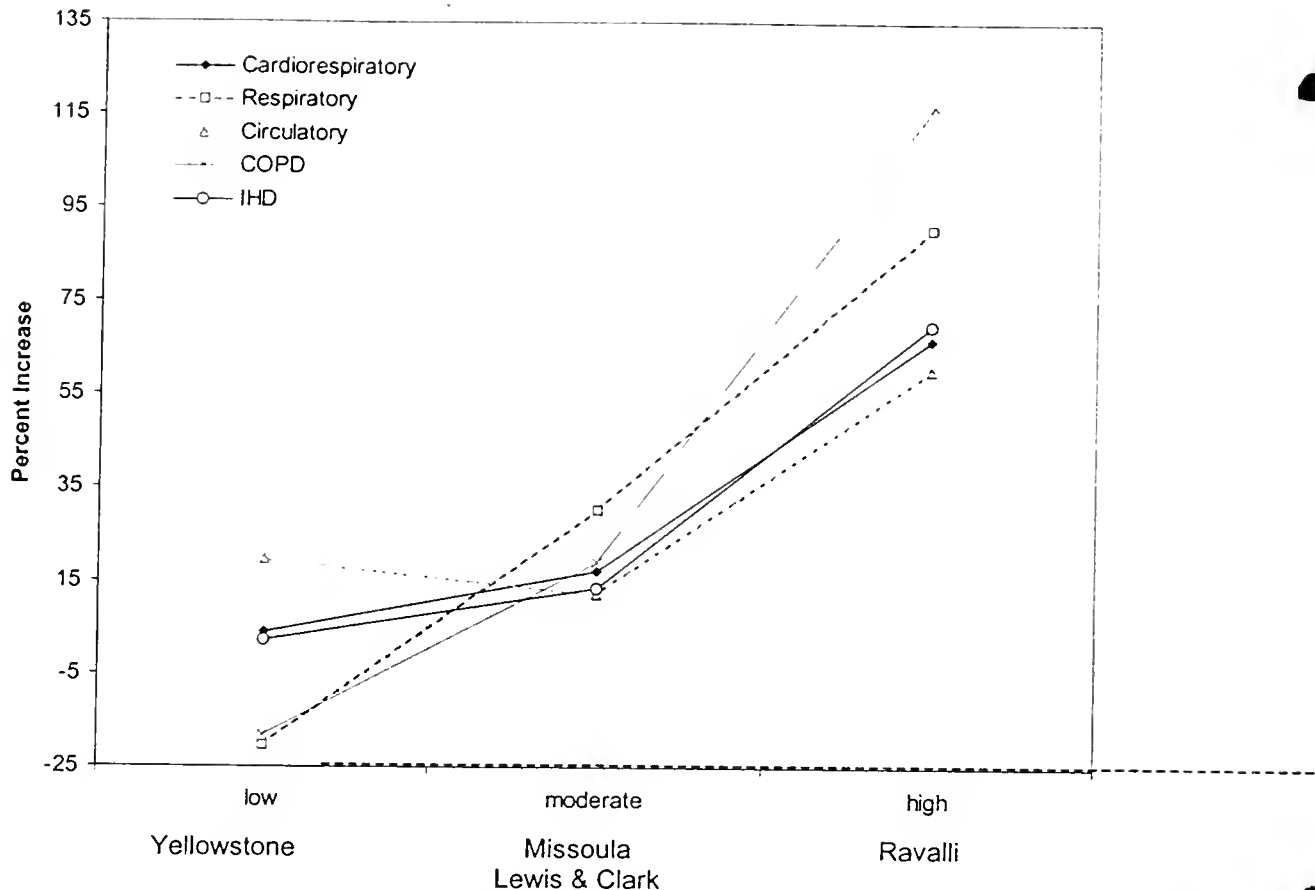


Figure 4. Percent Increase in Admissions Rate in Smoke Exposed Areas, 1999 &2000

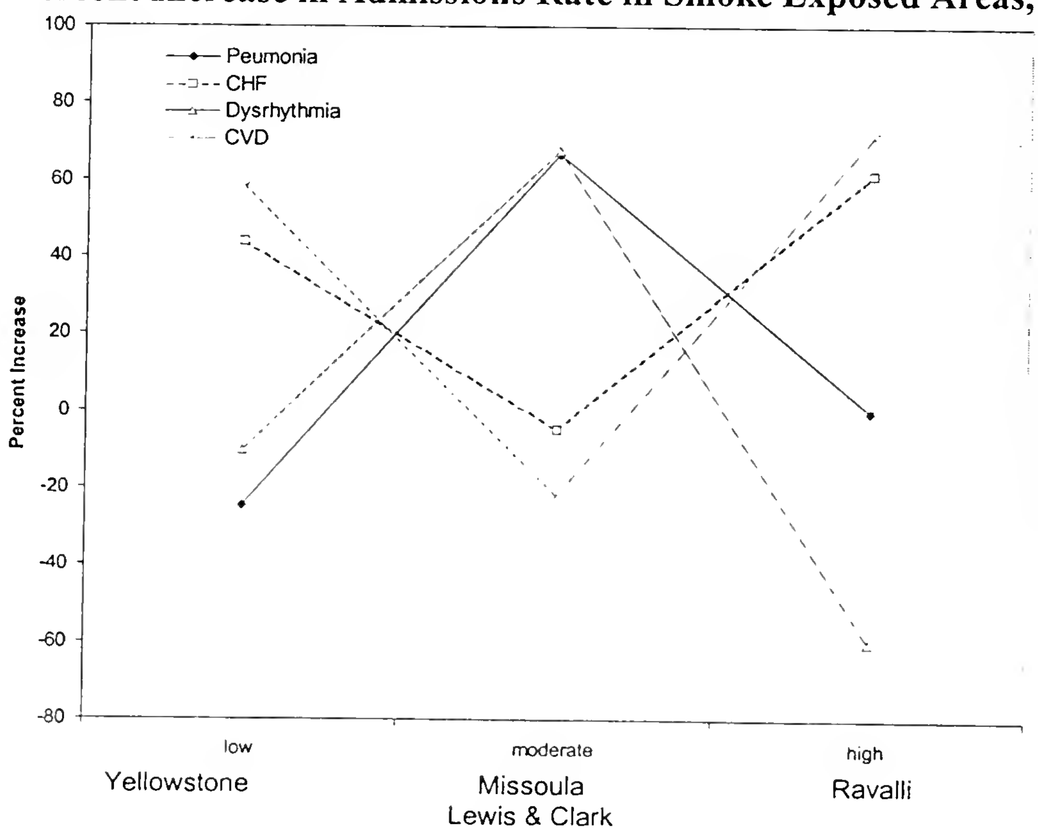
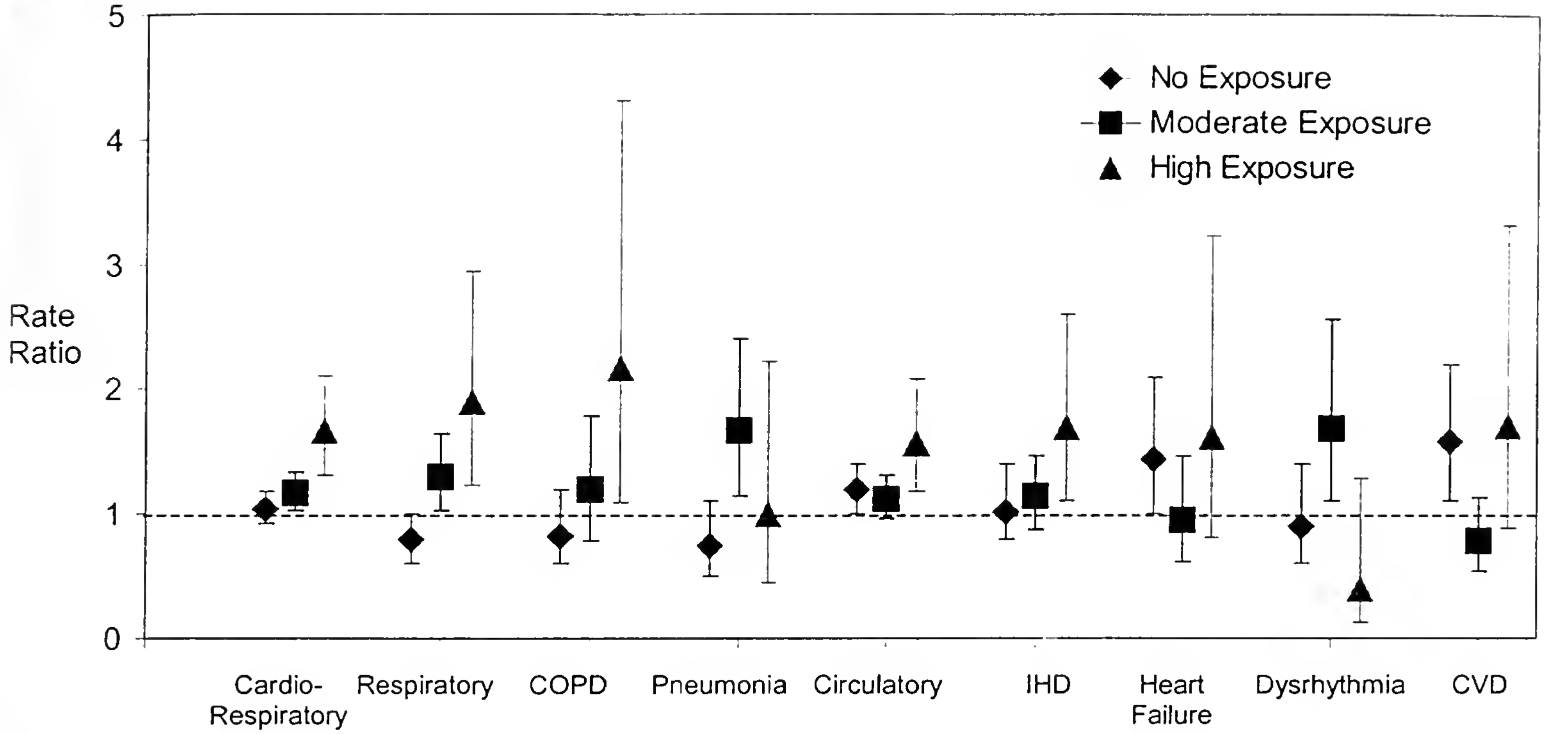


Figure 5. Percent Increase in Admissions Rate in Smoke Exposed Areas, 1999 &2000



gure 6. Rate Ratios for Admission in 2000 Compared to 1999 for Each Exposure Level

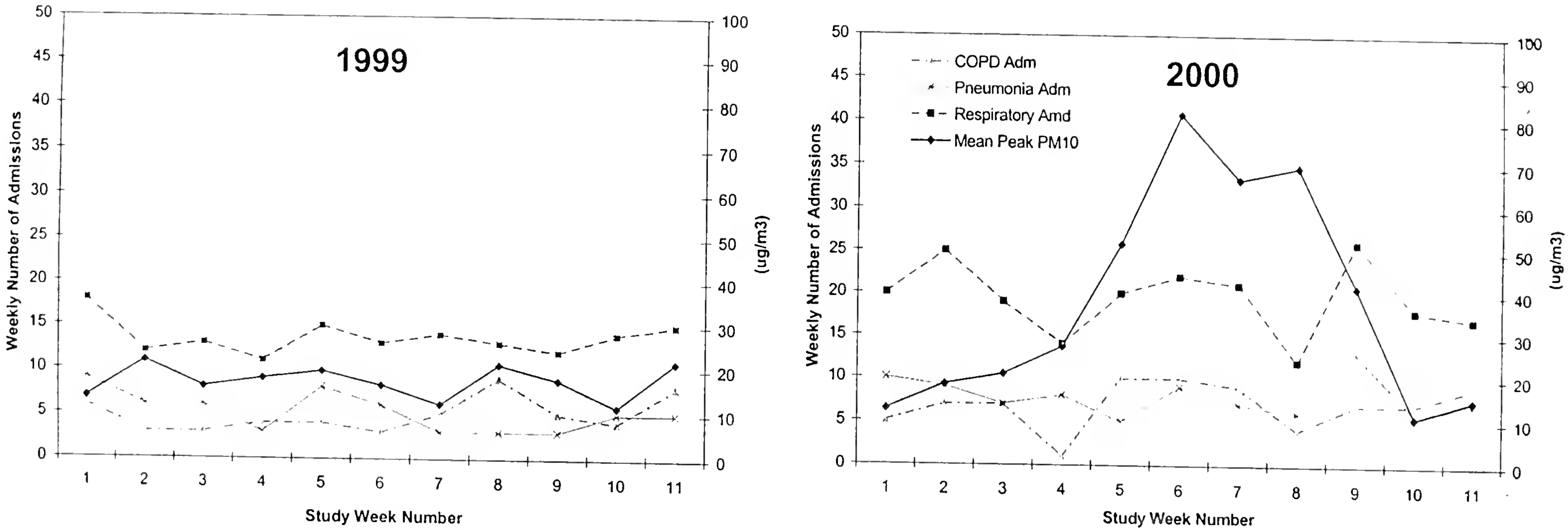


Figure 7a & b. Weekly Average PM10 plotted against Weekly Sums of Respiratory Hospital Admissions, 1999 & 2000.

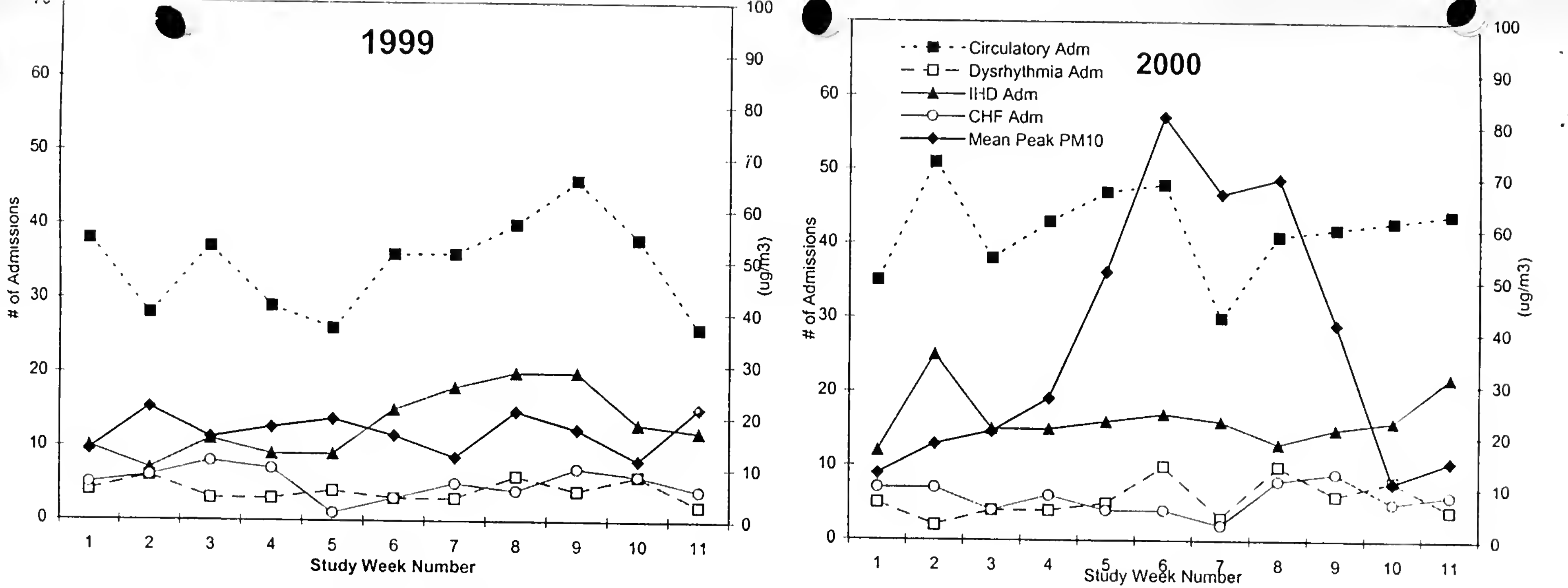


Figure 8a & b. Weekly Average PM10 plotted against Weekly Sums of Circulatory Hospital Admissions, 1999 & 2000

Appendix A. Abstraction Form

Montana Fires Data Abstraction Form

Hospital Number ________
MRN________________

Part I

CASE DEFINITION SCREEN: Do Primary or Secondary *Discharge* Diagnoses Include:

1) Any Circulatory Disease?

Yes __ No __ ICD-9 (ICD-9 390-459)

2) Any Respiratory Disease?

Yes __ No __ ICD-9 (ICD-9 460-519)

If YES to 1 or 2 above, then continue (if patient is still in hospital, then go to charts for case confirmation)....

Primary diagnosis on admission ________________________________ ICD-9 Code ________

Primary diagnosis on discharge ________________________________ ICD-9 Code ________

SECONDARY ICD-9 CODES ON DISCHARGE:

Circulatory Diseases (circle category then include specific codes)

Acute and Chronic Rheumatic Heart Disease (390-398—include codes after the decimal in parentheses)

390 RF Without Heart Involvement ( )
391 RF With Heart Involvement ( )
392 Rheumatic Chorea ( )
393 Chronic Rheumatic Pericarditis ( )
394 Diseases of Mitral Valve ( )
395 Diseases of Aortic Valve ( )
396 Diseases of Mmitral and Aortic Valves
397 Other Endocardial Structures ( )
398 Other Rheumatic Heart Disease ( )

Hypertensive Disease (401-405—include codes after the decimal in parentheses)

401 Essential Hypertension ( )
402 Hypertensive Heart Disease ( )
403 Hypertensive Renal Disease ( )
404 Hypertensive Heart and Renal ( )
405 Secondary Hypertension ( )

Ischemic Heart Disease (410-414—include codes after the decimal in parentheses)

410 Acute MI ( )
411 Acute IHD ( )
412 Old MI ( )
413 Angina ( )
414 Chronic IHD ( )

Diseases of Pulmonary Circulation (415-417—include codes after the decimal in parentheses)

415 Acute PHD ( )
416 Chronic PHD ( )
417 Other Pulmonary ( )

Montana Fires Data Abstraction Form

Hospital Number ________
MRN ________________

Circulatory Diseases (continued)

Other Forms of Heart Disease (420-429)

420 Pericarditis ( ) 421 Endocarditis ( ) 422 Myocarditis ( )

423 Other Pericardium ( ) 424 Other Endocardium ( ) 425 Cardiomyopathy ( )

426 Conduction ( ) 427 Dysrhythmia ( ) 428 Heart Failure ( )

429 Ill-defined Complications ( )

Cerebrovascular Disease (430-438)

430 Subarachnoid Hemhorrhage ( ) 431 Intracerebral Hemhorrhage ( )

432 Other Hemhorrhage ( ) 433 Precerebral Occlusion ( )

434 Cerebral Occlusion ( ) 435 Transient Ischemia ( )

436 Acute, Ill-Defined ( ) 437 Other Ill-defined ( ) 438 Late Effects ( )

Diseases of the Arteries Arterioles and Capillaries (440-448— codes after the decimal in parentheses)

440 Atherosclerosis ( ) 441 Aortic Aneurism ( ) 442 Other Aneurism ( )

443 Other Vascular ( ) 444 Arterial Embolism and Thrombosis ( )

446 Polyarteritis Nodosa and Allied Conditions ( ) 447 Other Arteries and Arterioles ( )

448 Disease of the Capillaries ( )

Diseases of Veins and Lynphatics and Other Circulatory (451-459

451 Phlebitis and Thrombophlebitis ( ) 452 Portal Thrombosis ( )

453 Other Embolism and Thrombosis ( ) 454 Varicose Veins Lower Extremities ( )

455 Hemhorrhoids ( ) 456 Varicose Veins Other Sites ( )

457 Noninfectious Disorders of Lymphatic Channels ( )

458 Hypotension ( ) 459 Other Disorders of Circulatory System ( )

Montana Fires Data Abstraction Form

Hospital Number_______
MRN_______________

Respiratory Diseases (circle category then include specific codes)

Acute Respiratory Infections (460 –466—include codes after the decimal in parentheses)

460 Acute Nasopharyngitis ( ) 461 Acute Sinusitis ( ) 462 Acute Pharyngitis ( )

463 Acute Tonsilitis ( ) 464 Acute Laryngitis or Tracheitis ( )

465 Other Acute URI ( ) 466 Bronchitis or Bronchiolitis ( )

Other URI Diseases (470–478—include codes after the decimal in parentheses)

470 Deviated Septum ( ) 471 Nasal Polyps ( ) 472 Chronic Pharyngitis ( )

473 Chronic Sinusitis ( ) 474 Chronic disease of tonsils and adenoids ( )

475 Peritonsillar abscess ( ) 476 Chronic laryngitis ( ) 477 Allergic Rhinitis ( )

478 Other URI ( )

Pneumonia and Influenza (480–487)

480 Viral Pneumonia ( ) 481 Pneumococcal Pneumonia ( )

482 Other Bacterial Pneumonia ( ) 483 Other Pneumonia ( )

484 Pneumonia in Infectious ( ) 485 Bronchopneumonia ( )

486 Unspecified Pneumonia ( ) 487 Influenza ( )

COPD and Allied Conditions (490–496)

490 Bronchitis not specified ( ) 491 Chronic Bronchitis ( )

492 Emphysema ( ) 493 Asthma ( )

494 Bronchiectasis ( ) 495 Extrinsic Alveolitis ( )

496 Other Chronic Obstruction ( )

Pneumoconioses and Other Lung Diseases (500-508—include codes after the decimal in parentheses)

500 Coal Workers Pneumoconioses ( ) 501 Asbestosis ( )

502 Pneumoconioses from silica ( ) 503 Pneumoconioses from inorganic dust

504 Pneumonopathy from other dust ( ) 505 Pneumoconiosis unspecified ( )

506 Respiratory from chemicals and vapors ( ) 507 Pneumonitis due to solids and liquids ( )

508 Respiratory problems from unspecified external agents ( )

Montana Fires Data Abstraction Form

Hospital Number _______
MRN________________

Respiratory Diseases (continued)

Other Disease of the Respiratory System (510-5198—include codes after the decimal in parentheses)

510 Empyema ( ) 511 Pleurisy ( ) 512 Pneumothorax ( )

513 Abcess of lung and mediastinum ( ) 514 Pulmonary Congestion and Hypostasis ( )

515 Postinflammatory Pulmonary Fibrosis ( ) 516 Other Alveolar Pneumonopathy ( )

517 Lung Involvement in Conditions Classified Elsewhere ( )

518 Other Diseases of the Lung ( ) 519 Other Diseases of the Respiratory System ( )

Admission and Discharge Information

Date of Admission: ___/___/___

Time of Admission: __________

Date of Discharge: ___/___/___

Discharged to:

1) Death
2) Home
3) Nursing Home
4) Other ____________________

Montana Fires Data Abstraction Form

Hospital Number _______
MRN _____________

Patient Demographics

Age: ________

Sex: 1. Male 2. Female

Race: 1. White 2. Black 3. Asian/Pacific Islander 4. American Indian 5.Other

County of Residence During Exposure Period:
1) Lewis and Clark
2) Missoula
3) Ravalli
4) Yellowstone

Zip Code of Residence During Exposure Period: ____________________

City of Residence During Exposure Period: ____________________

Part II

Information to be Obtained from Chart Extraction

Signs and Symptoms on Admission: ☐ yes ☐ no ☐ not reported

1. Breathing difficulty
2. Chest Pain
3. Cough
4. Eye Irritation
5. Nasal Irritation
6. Headache
7. Sore Throat
8. Not Reported
9. Edema
10. Other ________________

History of Respiratory or Circulatory Illness: ☐ yes ☐ no ☐ not reported

If yes, list symptom or conditions:
1) Coronary Artery Disease
2) High Blood Pressure
3) Cerebrovascular Disease
4) Atherosclerosis
5) COPD
6) Emphysema
7) Chronic Bronchitis
8) Asthma
9) Other ____________________

Previous Admissions for Respiratory or Circulatory Illness: ☐ yes ☐ no ☐ not reported
1) ________________
2) ________________
3) ________________
4) ________________

Medications at Admission: ☐ yes ☐ no ☐ not reported
1) ________________
2) ________________
3) ________________
4) ________________

Current Cigarette Smoker ? ☐ yes ☐ no ☐ not reported

Ever Cigarette Smoker ? ☐ yes ☐ no ☐ not reported

Occupation: ____________________________ ☐ not reported

Appendix B. Counts of Hospital Admissions by Cause

Table B-1. 1999 & 2000 Counts of Admissions for Respiratory Causes by Month.

County	Month	Total		COPD		Pneumonia	
		1999	2000	1999	2000	1999	2000
Ravalli	July	18	31	5	11	11	5
(pop=35811)	August	8	20	4	10	1	5
	September	5	8	3	5	0	2
	Total	31	59	12	26	12	12
Missoula	July	24	26	7	5	10	15
(pop=89344)	August	24	37	8	12	9	18
	September	9	15	5	7	3	7
	Total	57	78	20	24	22	40
Lewis & Clark	July	22	31	6	8	9	17
(pop=54075)	August	24	31	11	13	7	12
	September	16	15	5	5	7	6
	Total	62	77	22	26	23	25
Yellowstone	July	73	67	22	20	24	22
(pop=127258)	August	76	59	22	21	29	21
	September	38	23	16	8	16	9
	Total	187	149	60	49	69	52